Biology of the Leafhopper, *Acia lineatifrons* (Naudé) (Homoptera: Cicadellidae), on Grapevines in the Western Cape*

Elleunorah Marais

Viticultural and Oenological Research Institute (VORI), Private Bag X5026, 7600 Stellenbosch, Republic of South Africa.

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The life history of *Acia lineatifrons* (Naudé) was studied on potted grapevines. At a constant temperature of 26°C the minimum pre-oviposition period of the females ranged from 5 – 10 days, and the incubation period of the eggs from 9 – 11 days. The mean development time of the five nymphal instars from hatching to adult emergence was 15 and 25 days at 26° and 20°C respectively. Field studies showed that *A. lineatifrons* overwintered in the adult stage on indigenous *Rubus* spp. and entered the vineyard from late October to early November. Populations peaked between middle February and the end of March. During winter the sex ratio on rubus was heavily female biased, but during the growing season it was slightly male biased on both the rubus and grapevines. Adult leafhoppers showed a preference for grapevines to rubus in the laboratory, but field studies indicate that host preference is not the sole reason for the colonization of grapevines by leafhoppers.

The leafhopper, *Acia lineatifrons* (Naudé), is widely distributed across tropical Africa (Theron, 1982). Although it has previously been recorded in southern Africa, it was first identified as a pest on grapevines in 1978 in the Tulbagh area (De Klerk, 1981). Since then leafhopper damage has been reported on grapevines all over the Western Cape. The feeding of *A. lineatifrons* on grapevines causes browning or discolouration of the leaves from the periphery inwards, eventually resulting in early leaf fall. These symptoms resemble the "hopper-burn" symptoms described by Moutous (1979) for *Empoasca vitis* Goethe on grapevines in the southwest of France and appear to be the result of a phytotoxic reaction.

The development of efficient pest management strategies to control this new pest on vines in the Western Cape necessitates knowledge of its biology. Since knowledge of the biology and population dynamics of *A. lineatifrons* is lacking, the present study was conducted to (a) determine the life cycle and egg to adult development time on grapevines; (b) identify the indigenous hosts on which the leafhopper overwinters; (c) determine the seasonal abundance of the leafhopper on grapevines; and (d) examine the sex ratio of the leafhopper populations on grapevines and on indigenous hosts. The recent wide-spread damage caused by *A. lineatifrons* on grapevines raised questions as to the possible reasons for the leafhopper's apparently sudden move from its natural host plants onto the vines. Host preference studies were therefore conducted in an attempt to find an explanation for the movements of *A. lineatifrons* onto the grapevines.

MATERIALS AND METHODS

Life history: The study was done at the Viticultural and Oenological Research Institute near Stellenbosch (33°55' S, 18°52' E) under controlled conditions. Potted Chenin blanc grapevines grafted onto 99 Richter rootstocks were used as host plants. Nymphs were collected from an infested vineyard, placed on potted grapevines in a screen cage and kept in a constant temperature room at 26°C. Virgin adult leafhoppers were collected from the cage as they emerged, and each female enclosed with one or two males in small cages on single vine leaves. All newly hatched nymphs produced by these adults were removed and placed singly in similar cages on single vine leaves at 20°C and 26°C. A long photoperiod of 18 hours was selected and special growth lights ("Grolux" neon tubes) were used to ensure normal, vigorous vine growth.

Daily observations were made and the dates of hatching, moulting and adult emergence recorded to determine the number of nymphal instars and development time of each nymph at 26°C. Exuviae were removed from the cages after every moult. At 20°C, however, only the total development time of nymphs was recorded.

The incubation period of eggs was determined at 26°C by placing pairs of newly emerged females and males in cages on single leaves and recording the dates on which the first nymphs hatched. Eggs are inserted under the leaf surface and are not visible to the naked eye. Females of *A. lineatifrons* are easily injured during handling and therefore they were transferred to fresh leaves every second or third day only. As a result the exact date of oviposition for each egg could not be determined, and the incubation period is given as a range over two to three days. The number of days each female spent on the leaves from which no nymphs hatched, was recorded to calculate the minimum pre-oviposition period.

Seasonal occurrence: Part of an infested vineyard (Chenin blanc grafted onto 99 Richter rootstocks) near Simondium (33°51' S, 18°57' E) in the Western Cape was divided into 100 plots of six vines each to study leafhopper migration, abundance and overwintering. These 100 plots were grouped into five blocks of 20 plots each in a randomised block design. The plots in each block were alloted numbers from one to 20 at ran-

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dom and a plot from each of the five blocks was sampled every week with a D-Vac suction sampler for one minute on one side of the row only. Thus each plot was sampled only once every 20 weeks during the growing season (September to May/June), which allowed the leafhopper population time to re-establish before the next sampling. This sampling method was effective for collecting adults only. Sampling commenced on 19 January 1982 and was carried out over three seasons until June 1984. After leaf fall the bare vines and the weeds in the vineyard were sampled once a week for three consecutive weeks to determine whether the leafhoppers overwintered there.

Two wild bramble species, *Rubus chrysocarpus* (Smith) and *R. pinnatus* Willd, growing adjacent to the experimental vineyard were also sampled. Three patches of *Rubus* spp. (each approx. 2–3 m in diameter), separated from the vineyard by a gravel road, were sampled alternately for one minute every week with a D-Vac suction sampler during spring and summer and every second week during winter.

The possible influence of temperature and rainfall on the leafhopper population was investigated by multiple linear regression. Daily maximum and minimum temperatures and daily rainfall figures for the period January 1982 until June 1984 were obtained from a meteorological station near the experimental site at Simondium. Since the number of adults present at any given sampling date would depend largely on the survival and development rate of the nymphs, the meteorological data were averaged from one to 20 days prior to sampling before multiple linear regression analysis was done.

Sex ratio: On six occasions during the winter of 1986 patches of *Rubus* spp. at sites near Simondium and Lynedoch were sampled with a D-Vac suction sampler and the numbers of *A. lineatifrons* males and females recorded. During the ensueing spring and summer random samples were taken weekly until March 1987 from the grapevines and the adjacent rubus patches near Simondium to determine the spring and summer sex ratio of *A. lineatifrons.*

Host preference: Leaves of *Rubus* spp. and grapevines were collected in the field, the bases of the petioles cut off under water and embedded in saturated "Oasis" (florist's sponge). One vine leaf and one rubus leaf of similar size and age were placed together in a large petri dish (145 mm diameter). Two or three *Acia lineatifrons* adults, collected from grapevines and *Rubus* spp. in the field, were placed equidistant from both leaves in each of the petri dishes. The position of the leafhoppers was recorded 90 minutes and again 20 hours after release. The experiment with adults collected from grapevines was replicated four times with 12, 14, 21 and 25 adults respectively. The experiment with adults collected from rubus was replicated three times with 20, 21 and 24 adults respectively. Because the two sets of data (90 minutes and 20 hours after release) were not obtained from independent samples, the data for the two sets were analysed separately. Chi-square tests were performed on the data to test for heterogeneity between replicates and for interaction between response and sources of leafhoppers, and to determine whether the leafhoppers preferred one host to the other.

RESULTS AND DISCUSSION

Life history

The minimum pre-oviposition periods calculated ranged from five to ten days (n = 15). The incubation period of the eggs at 26°C ranged between 7 – 10 days and 14 – 16 days with a mean range of 9 – 11 days (n = 16). Five nymphal instars were recorded at 26°C. Various other leafhopper species in Europe, North America, Asia and Africa have also been found to moult five times before the adult stage, although certain conditions have been known to cause some leafhopper species to pass through only four or as many as six nymphal instars (DeLong, 1971).

The durations of the nymphal stages at 20°C and 26°C are shown in Table 1. Data of nymphs that died or escaped before adult emergence were excluded. The mean duration of each of the first four instars at 26°C was less than three days, whereas the fifth instar took four days on average to complete. The mean development time from hatching of the nymphs until adult emergence was 15 and 25 days at 26°C and 20°C respectively. The observed developmental rate at 26°C adds up to a mean generation time of 29 – 36 days, where generation time is taken as the period from the day an egg is laid until the female emerging from the egg begins ovipositing.

TABLE 1. Nymphal development period of *Acia lineatifrons* at two temperatures.

	Development period (days)						
	26°C						20°C
	Instar 1	Instar 2	Instar 3	Instar 4	Instar 5	Overall*	Overall*
Mean	2,7	2,5	2,9	2,9	4,1	15,1	25,0
Range	2 - 4	2 - 4	2 - 5	1 - 4	1 - 6	12 - 20	21 - 30
SD	0,69	0,78	0,95	0,83	0,83	1,96	2,39
No. of insects	24						17

* Overall = from hatching of nymph until adult emergence

It is well-known that the temperature-dependent development rate of an insect is a fundamental feature of its life history. Although only two temperatures were used in this study, the results suggest that *A. lineatifrons* is very sensitive to temperature changes, and that an increase in temperature within the tolerance limits of the leafhopper would favour the development rate, as was also indicated for other leafhopper species such as *Cicadulina mbila* (Naudé) (Rose, 1973; Van Rensburg, 1982a). The number of generations per year in a multivoltine species such as *A. lineatifrons* would, therefore, be largely influenced by prevailing temperatures.

Seasonal occurence

Figure 1 shows the occurrence of *A. lineatifrons* on grapevines over three seasons. The first adults appeared on the vines from late October to early November, but their numbers only increased rapidly from December to reach a peak between the middle of February and the end of March. After leaf fall (from July to September) no leafhoppers were found on the vines or on the weeds in the vineyard. Symptoms of leafhopper damage to the vines appeared shortly before the population peaks were reached.

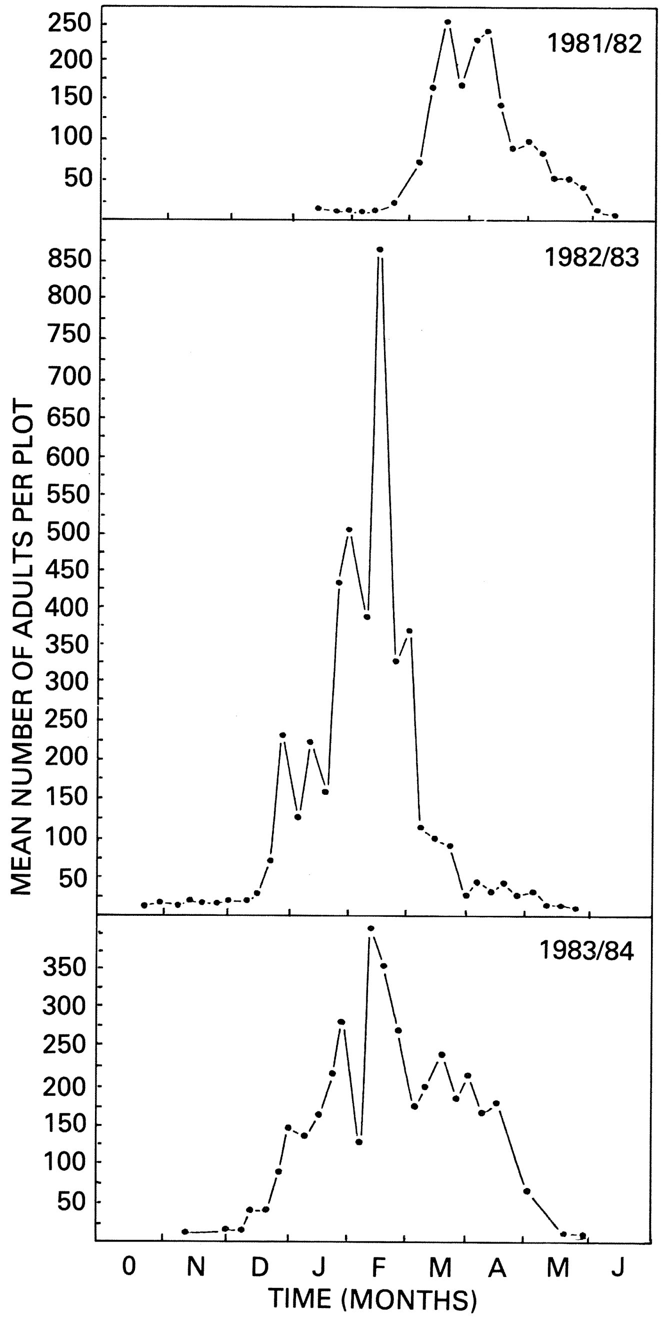

Figure 1. Seasonal occurrence of *Acia lineatifrons* on grapevines at Simondium over three seasons.

Since acephate is very effective against *A. lineatifrons* (Marais & De Klerk, 1985), the delay in the population build-up of the leafhoppers observed for the 1981/82 season may be ascribed to the application of this insecticide to the vineyard on 18 December 1981 for snoutbeetle (Curculionidae) control. No insecticides were applied to the experimental vines thereafter for the duration of the study.

It was often observed that the wings of adults stuck to wet leaves during the rainy season, which resulted in high mortality. Despite remarkable differences in rainfall over the different seasons, attempts to explain seasonal fluctuations in leafhopper numbers in relation to precipitation and temperature data failed. This should be attributed to a lack of data over a much longer period. Nevertheless, it is possible that the lower rainfall during 1982 may have resulted in a higher rate of adult survival during winter which, in turn, could have contributed to the higher population peak in the 1982/83 season compared to the 1983/84 season.

Adults of *A. lineatifrons* were found on *Rubus* spp throughout the year (Fig. 2). As the sampling regime may not have allowed the leafhopper population enough time to re-establish properly, these counts may serve only as an indication of the presence or absence of *A. lineatifrons* in the immediate vicinity of the vines, and may not truly reflect its numbers on rubus. During the growing season both adults and nymphs were observed, but since only adults were found during winter, it is concluded that *A. lineatifrons* overwinters in the adult stage on indigenous *Rubus* spp.

The fact that *A. lineatifrons* occurs on rubus throughout the year means that the rubus supplies a constant source of leafhopper infestation. This raises the question whether the leafhoppers could be controlled by applying a pesticide to the rubus. This is not considered feasible, as wild rubus rarely occurs in monocultural stands, but is usually interspersed with other indigenous plants like bracken and *Rhus* spp, forming dense, virtually impenetrable thickets. Furthermore, pesticide applications to the rubus could also have wide-ranging effects on the natural enemies of *A. lineatifrons* and other insects occuring on the rubus. Wild birds like guinea-fowl and partridges also eat the berries of rubus and would be adversely affected by the pesticides.

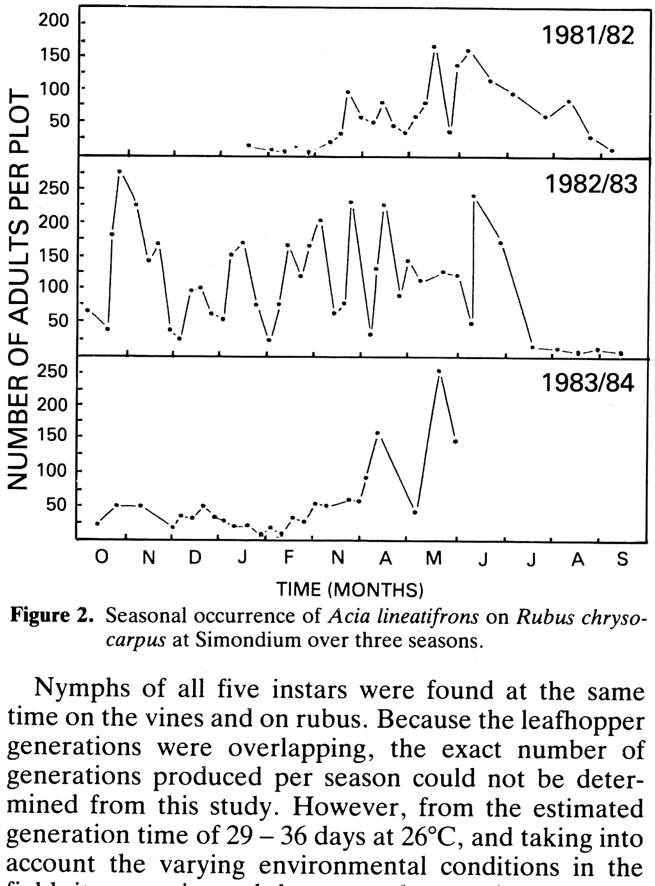

Figure 2. Seasonal occurrence of *Acia lineatifrons* on *Rubus chrysocarpus* at Simondium over three seasons.

Nymphs of all five instars were found at the same time on the vines and on rubus. Because the leafhopper generations were overlapping, the exact number of generations produced per season could not be determined from this study. However, from the estimated generation time of 29 – 36 days at 26°C, and taking into account the varying environmental conditions in the field, it was estimated that up to three or four leafhopper generations could be produced per year under favourable conditions.

Sex ratio

The sex ratio of a population plays an important role in determining the rate of increase of the population.

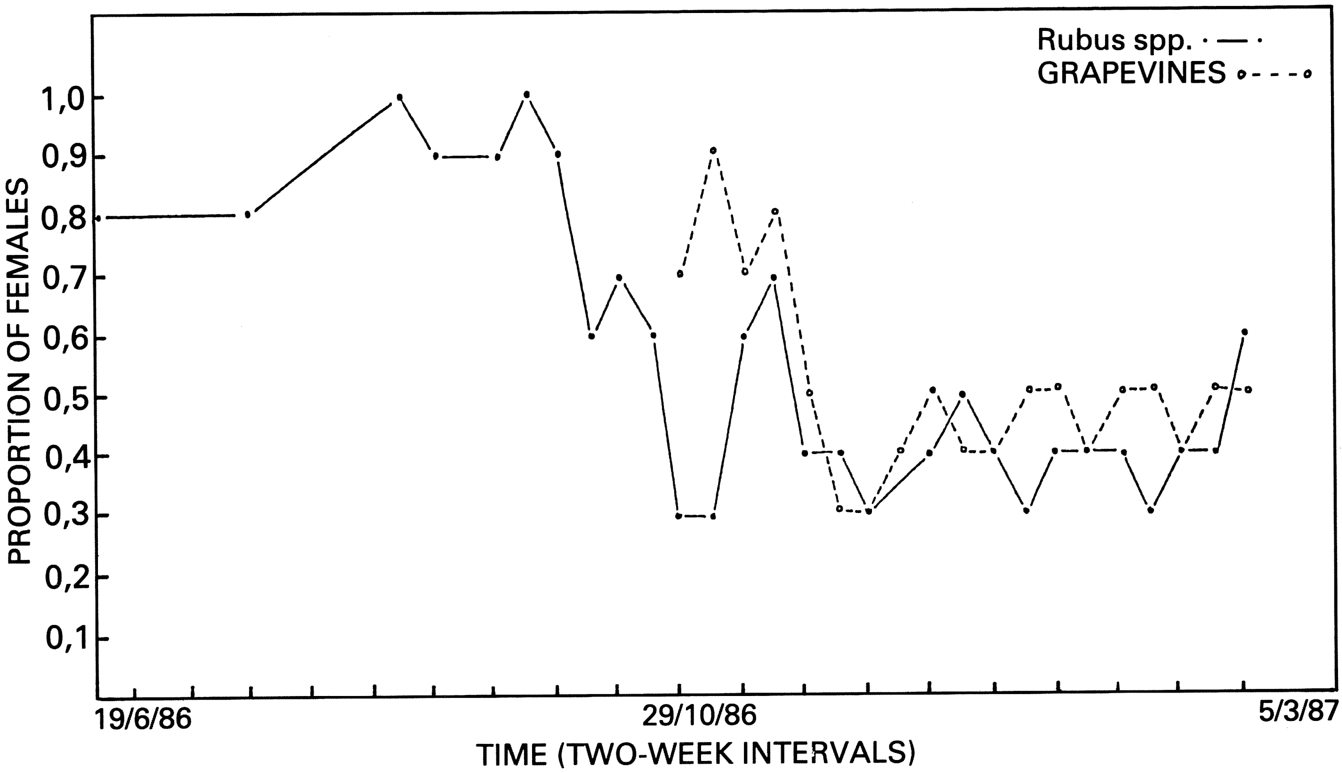

Figure 3. Sex ratio of *Acia lineatifrons* on *Rubus chrysocarpus* and on grapevines during the 1986/87 season at Simondium.

Figure 3 shows the observed sex ratio of *A. lineatifrons* on rubus and grapevines. The sex ratio of the overwintering leafhopper population on rubus was heavily female biased. With the advent of spring there was a marked swing towards a predominantly male biased sex ratio. The sex ratio on the grapevines was female biased when leafhoppers first began to move onto vines (29/10/86), although the sex ratio on rubus had changed to male biased by that time. This may be due to the migration of mainly females from rubus to the vines during spring. Soon after, however, the ratio on vines also became male biased. Although the sex ratio attained a 1:1 proportion on several occasions, the overall trend during summer was male biased on both host plants. The shift towards a heavily female biased sex ratio during winter was most likely due to differential mortality of the sexes, with the females better surviving winter conditions. The possibility that mating takes place before winter cannot be excluded and needs to be investigated.

Host preference

The results of the host preference tests appear in Table 2. As the Chi-square tests for heterogeneity between the replicates and for interaction between responses and sources of leafhoppers were not significant, the data for the adults from grapevines and from *Rubus* were pooled. Chi-square values were calculated for the pooled results after 90 minutes and 20 hours respectively to determine if *A. lineatifrons* adults prefer grapevines or *Rubus* (Table 2). These indicate that adult leafhoppers have a statistically significant preference for grapevines after 90 minutes ($P < 0,02$). After 20 hours there was no significant preference for either host. However, the possibility that this apparent change in preference was the result of changes in the leaves overnight or the artificial experimental conditions cannot be excluded.

The leafhopper's indigenous hosts, *R. chrysocarpus* and *R. pinnatus,* are evergreen perennials with regular flushes of new growth all year round. *A. lineatifrons* is,

TABLE 2. Host preference of *Acia lineatifrons* adults collected from grapevines and from *Rubus* spp.

Source of Adults	Time after release	Rubus	Grapevines	Container* surface
Grapevines	90 min.	4	6	4
	20 h	8	4	2
	90 min.	3	9	0
	20h	6	5	1
	90 min.	5	11	5
	20 h	10	11	4
	90 min.	10	11	4
	20 h	13	12	0
Grapevines pooled	90 min.	22	37	13
	20 h	39	30	3
Rubus	90 min.	6	13	2
	20 h	11	10	0
	90 min.	9	11	4
	20 h	12	10	2
	90 min.	7	11	2
	20 h	6	12	2
Rubus pooled	90 min.	22	35	8
	20 h	29	32	4
Pooled overall	90 min.	44	72	21
	20 h	68	62	7

* Not taken into account for the calculations

Chi-square for pooled data after 90 min. = 6,285 with one degree of freedom at alpha = 0,05

Chi-square for pooled data after 20 hours = 0,192 with one degree of freedom at alpha = 0,05

Critical value of Chi-square with one degree of freedom = 3,841 at alpha = 0,05 therefore, not forced to seek alternative hosts, as in the case of *Cicadulina* spp. where migration occurs due to the influcence of seasonal change on host plants (Rose, 1972; Van Rensburg, 1979). Due to the presence of large leafhopper populations on the rubus throughout the year it seems unlikely that the colonisation of the grapevines at the beginning of the growing season by adults of *A. lineatifrons* that had overwintered on rubus was prompted solely by a preference for grapevines. Host plants can also influence the fecundity and development rate of leafhoppers (Van Rensburg, 1982b). The possibility that grapevine hosts favour fecundity and the developmental rate of *A. lineatifrons* and thus contributes to the recently observed leafhopper outbreaks on vines, needs further investigation.

Hatching of the nymphs through five instars until adult emergence was 15 and 25 days at 26°C and 20°C respectively. The minimum pre-oviposition period of the females ranged from 5 – 10 days, and the incubation period of the eggs from 9 – 11 days at 26°C. This adds up to a generation time of 29 – 36 days at 26°C. Field studies showed that *A. lineatifrons* overwintered in the adult stage on *R. chrysocarpus* and *R. pinnatus* and entered the vineyard during late October to early November, after the new vine leaves had unfurled. Peak populations can be expected between the middle of February and the end of March and damage to leaves become really noticeable shortly before the population peaks are reached.

During winter the sex ratio of the leafhopper population on the rubus was heavily female biased, but during the growing season it tended to be slightly male biased on both the grapevines and rubus. Host preference tests revealed a slight preference for grapevines. However, in the light of the high leafhopper populations occurring on rubus all year round, it seems unlikely that the leafhoppers move onto the grapevines solely because of a preference for grapevines.

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